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PETRIFIED COALS AND THEIR BEARING ON THE PROBLEM
OF THE ORIGIN OF COALS

By Edward C. Jeffrey

BOTANICAL LABORATORY, HARVARD UNIVERSITY

Communicated by J. M. Clarke, February 3, 1917

In recent years I have published two preliminary articles on the conditions of formation of coal based upon a study of the internal organization of a large number of coals from various geographical regions and different geological horizons.^{1,2} The success of these investigations has been based on improved methods, which are recorded in an article recently published.³ The conclusion reached, contrary to the usually accepted opinion supposed to be based on reliable stratigraphic evidence is that coal is not in general a deposit laid down *in situ* but is composed of drift materials deposited in open water. The arguments from structure for this opinion seem to be overwhelming, for the typical organization of the numerous coals investigated is entirely canneloid. Since cannel coal is universally conceded to be a deposit accumulated in open water, it follows that the great mass of coals must have been accumulated under similar conditions to those admitted for cannels and oil shales as a consequence of their structure. The present writer accordingly on the basis of new facts arrived at by new and improved methods, must announce his adhesion to the doctrine of coal formation long held in France, namely that this invaluable mineral is formed of drift material laid down in open water and does not correspond at all to the peat deposits formed on land in the present epoch and in temperate climates.

The strongest argument supplied from the structural standpoint for the origin in place of coal is that provided by petrified coals, or as they are often designated 'coal balls.' A very interesting summary account of these structures, with special reference to those occurring in the British Isles, was published some years ago.⁴ The conclusion is here reached that the Upper Foot Seam as well as other English and Continental seams of higher and lower geological level, which contain the masses of petrified vegetation known as 'coal balls' consist of vegetable materials accumulated in sea water or at least water that was saline. The preservation of the remains during the years of accumulation is attributed to the antiseptic properties of sea water. It is apparently an unnecessary assumption since very delicate vegetable structures are found at the present day at depths of from three to ten meters in post glacial lacustrine accumulations. It must further be pointed out that the laying

down of vegetable materials in saline estuarial basins, even if this mode of accumulation be conceded, is very far from complying with the conditions of *in situ* formation.

An interesting feature of the organization of 'coal balls' which apparently has not previously been emphasized vouches strongly for the accumulation of their constituents under open water conditions. Very frequently masses of charcoal are found distributed irregularly and without any principle of stratification through the petrified substance of the ball. This burned material irregularly disposed can only be explained naturally as the result of the washings of the relics of forest fires into open water, as often occurs in the case of our actual lakes. In figure 1 is shown part of a 'coal ball' showing on one side Cordaitan wood which had not been burned previous to mineralization and on the other side black woody material which shows all the evidence of transformation into charcoal.

It is sometimes assumed that the occurrence of a peat-like organization in the coal balls vouches for their accumulation *in situ*. Nothing could be further from the truth. The use of the peat probe designed by the late Dr. C. A. Davis of the U. S. Bureau of Mines, in the case of lacustrine accumulations which are still covered by open water, has convinced the author that material, which superficially resembles ordinary peat is formed often at considerable depths, from the sinking of the water-logged twigs, leaves, cones, etc., of land plants to the bottom. Such an accumulation is shown in sections in figure 2, which represents material probed at about the depth of two meters under the open waters of a small lake in Eastern Quebec. It strikingly resembles in appearance the organization of the 'coal balls' shown in figure 1. An organization like that of land peat is consequently clearly not convincing evidence of the terrestrial origin in the case of masses of petrified coal.

It will be convenient next to consider the organization of the coals which surround the petrifications known as 'coal balls'. Figure 3 illustrates the structure of a coal derived from the well known Upper Foot Seam of Lancashire, England, from which so many of the English 'coal balls' have been secured. The cutting of successful sections of coals from seams producing 'coal balls' has proved to be a matter of considerable technical difficulty on account of the lack of bituminous binding material in such coals. The coals in question have to be held together with wrappings during the process of softening and must receive just the right degree of treatment with hydrofluoric acid and nascent chlorine to furnish utilizable sections. The general results here recorded depend on the examination of the structure of the three different samples of

English coals containing 'coal balls,' which the author owes to the kindness of Dr. Marie Stopes of the University of London whose investigations on the origin of these petrifications are known to all (4). Through the kindness of Dr. M. Zalesky of the Comité Geologique of Petrograd similar coals have been secured from the great Donetz coal fields of Russia. To the administration of the Geologische Landesanstalt of Prussia, the author owes material of the dolomitic so-called 'Torfkohle' of Westphalia. It will be seen that there has been no dearth of appropriate materials for investigation. The organization in every case has been proved to be the same and is that shown in figure 3. This represents a substance which is composed of darker and lighter bands, more or less interrupted by cracks in the matrix of the coal. The lighter zones correspond to modified woody material present in the original accumulation and the darker stripes to more perishable matter, to judge from the situation in the bottom deposits of existing lakes, often consisting of the excrements of aquatic animals, such as molluscs, fish and amphibia, as well as the more delicate and destructible parts of plants. Where the woody material is massive the resulting coal is frequently quite homogeneous in its character and corresponds to the lighter substance shown in figure 3. The type of organization shown in the figure under discussion is frequent in the higher grade coking coals of the United States, namely those of Pennsylvania and Virginia. Practically no petrified coals however have yet been described for the North American continent.

Figure 4 exemplifies the organization of a typical coal from Lancashire, England. This illustration shows the presence of a large number of light bodies, which are flattened spores. A very large spore (a so-called megaspore) is seen in the lower region, while innumerable smaller ones are scattered throughout the substance of the coal. In addition to the spores are seen bands of darker hue corresponding to much modified wood and black zones which represent the more perishable parts of the original materials from which the combustible has been derived. The bands of the coal under discussion have their counterpart in similar structures shown in figure 3. In the coal ball however the innumerable spores of figure 4 are conspicuous by their absence. It will at once be apparent to the reader that ordinary bituminous coals are much more like cannel in their organization than like that of the seams in which the petrifications known as 'coal balls' occur. It is thus clear that ordinary bituminous coal must, if structure is a reliable criterion of origin, have been produced under similar conditions to cannel. It is universally admitted that cannel coals are of lacustrine origin and owe

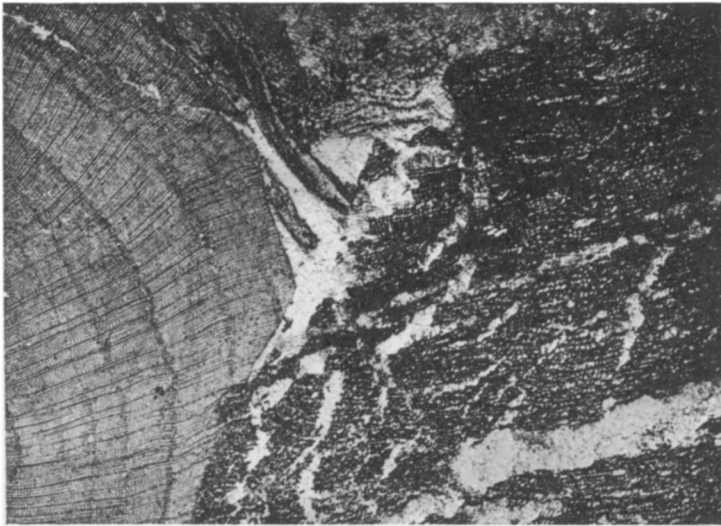


FIG. 1

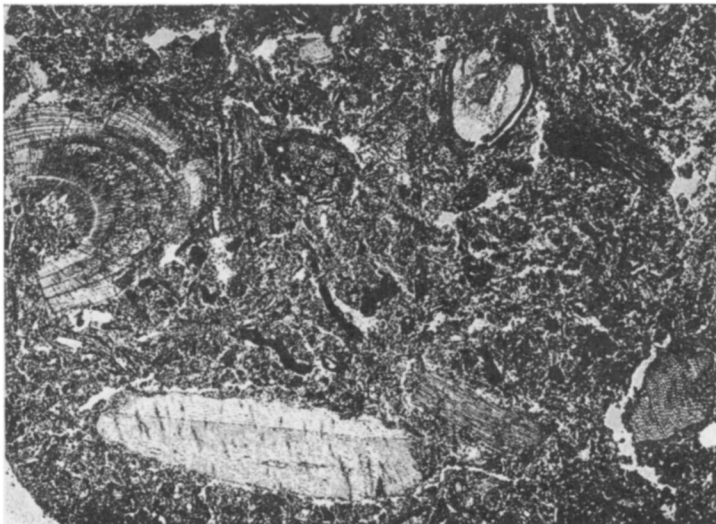
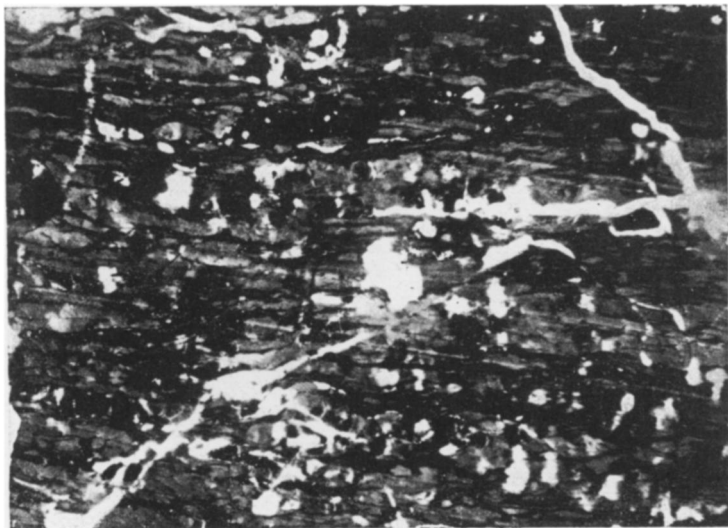
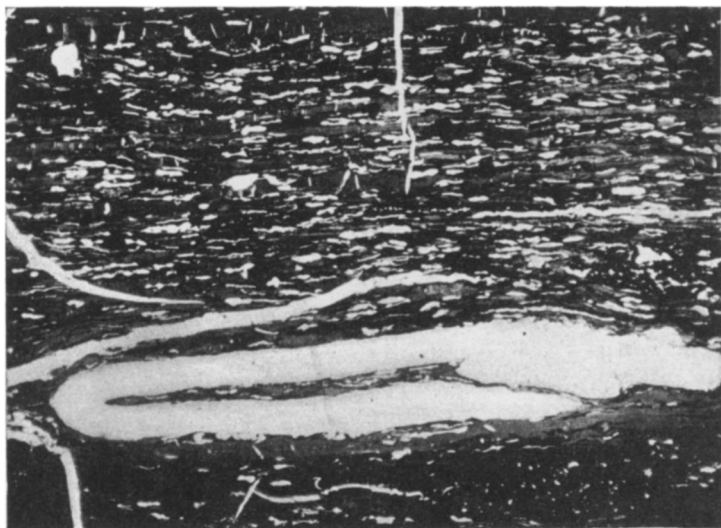


FIG. 2

**FIG. 3****FIG. 4**

their accumulation to the bringing of vegetable material from elsewhere by air and by water transport. It follows that the commoner coals have had a similar derivation since they have practically an identical organization.

It may be summarily stated in conclusion, that there is no good evidence that 'coal balls' are organized from material accumulated *in situ*. The facts that they often include isolated masses of charred vegetable matter and that identical material to that composing their substance is often accumulated under modern conditions, by transport and sedimentation in open water, furnish very strong evidence of their formation from transported material. Further the coals in which 'coal balls' have been found are abnormal coals singular by the absence of spore material which is a striking feature of the organization of typical coals of every geological age and all geographical regions. The structure of the coals containing the 'coal balls' cannot consequently be used as an argument in favor of the *in situ* origin of coals in general, even if it were proved that they themselves had been accumulated in this manner, which, as has been shown above on the basis of the organization of 'coal balls,' is very far from being established. The great mass of coals by their close resemblance in organization to cannel coals show that they have been laid down under the open water and transport conditions, which are universally conceded for the coals of the canneloid category. A fuller account with evidence in greater detail will appear at a later date.

¹ Jeffrey, E. C., *Economic Geology*, 9, 1914, (730-742).

² Jeffrey, E. C., *Chicago J. Geol. Univ. Chic.*, 23, 1915, (218-230).

³ Jeffrey, E. C., *Science Conspectus*, Boston, 6, 1916, (71-76).

⁴ Stopes and Watson, *London Phil. Trans. R. Soc.*, B. 209, 1907, (167-218).

THE EFFECT OF DEGREE OF INJURY, LEVEL OF CUT AND TIME WITHIN THE REGENERATIVE CYCLE UPON THE RATE OF REGENERATION

By Charles Zeleny

DEPARTMENT OF ZOÖLOGY, UNIVERSITY OF ILLINOIS

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1. *Degree of Injury*.—In a former series of papers the writer gave the results of experiments on the effect of degree of injury upon the rate of regeneration. A number of different species of animals and various combinations of injuries were involved. The results obtained tend to show that on the whole, within certain limits, the rate of regeneration